CENTRAL EXPERIMENTAL FARM,

DEPARTMENT OF AGRICULTURE.

OTTAWA, - - - - CANADA.

BULLETIN No. 3.

MARCH 15th, 1888.

To the Honourable the Minister of Agriculture:

Sir,

I have the honour to submit herewith the third Bulletin of the Central Experimental Farm. This has been prepared at my request by Mr. James Fletcher, the Entomologist and Botanist of the Dominion Experimental Farms, and relates to the "Smuts affecting Wheat," a subject of much importance to farmers in every Province of this Dominion. The annual loss to the grain growers of Canada, caused by these several species of smut is very large, and as this loss may be easily prevented I have thought it desirable that this matter should be brought early and prominently under the notice of the farmers of this country, that the fullest information regarding the life history of these parasitic fungi should be presented together with such useful remedies as can be cheaply got and easily applied. In many parts of the North West the "bunt" smut is very prevalent, and in this instance the injury sustained is not alone the loss of the infected grain—itself a considerable item—but as this fetid smut is carried with the grain to the threshing machine and is there scattered throughout the mass of the wheat, the entire crop is depreciated in value and in some instances acquires so strong and unpleasant an odour as to become quite unsaleable for milling purposes.

As the time for sowing is now approaching, it is hoped that every farmer who has the slightest reason to suspect that his seed grain may be contaminated with the germs of either of these destructive parasites will treat it in accordance with the directions given in the latter part of this Bulletin under the head of "remedies." If this is generally done a great saving will be effected to the country and much after disappointment prevented.

I have the honour to be,

Your obedient servant,

WM. SAUNDERS,

Director.

Ottawa, March 15th, 1888.

CENTRAL EXPERIMENTAL FARM.

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DEPARTMENT OF AGRICULTURE

OTTAWA, - - CANADA.

SMUTS AFFECTING WHEAT.

BY JAMES FLETCHER, F.R.S.C., F.L.S.

Entomologist and Botanist to the Dominion Experimental Farms.

The large amount of loss to the wheat crop every year, from the attacks of the low forms of vegetable life known as Parasitic Fungi, is now universally acknowledged; but the enormous extent of this injury is only appreciated by those who specially turn their attention to the matter. For an evidence of the magnitude of this injury we may consult the Report of the United States Commissioner of Agriculture for 1886, where we find the following words: "we may safely assume that the value of the corn and wheat annually destroyed in this country by diseases induced by fungi is not less than $200,000,000." This large sum of course also includes the injury caused by "Rusts" and "Mildews" as well as "Smuts."

Fungi is a Latin word (plural of *Fungus*) which is applied to a large class of flowerless plants of which Toadstools, Mushrooms and the large ear-shaped woody growths, sometimes found on forest trees, are conspicuous examples. There are, however, also included in this class many small forms which are not so readily recognized by the ordinary observer as fungi. Amongst these we find the "Moulds" which appear upon provisions when left in a warm and damp atmosphere, and also the "Smuts," "Mildews" and "Rusts" which are the chief agents in inflicting the heavy losses in grain and fruit crops already referred to.

Fungi differ very much from the ordinary forms of vegetation around us. They have neither true roots, stems, leaves, flowers, nor seeds. They are, however, unmistakeably plants, of low organization it is true, but still plants developed from germs called *spores*, somewhat analogous to, but not the same as, the seeds of the more highly organized flowering plants. A spore is a reproductive body which answers the same purpose as a seed by providing for the perpetuity of the species of plant which produces it; but has not like the true seed, a rudimentary plant already formed within it. The processes of development, fertilization and reproduction amongst these low forms of vegetable life, are as yet, with few exceptions, little understood. This is chiefly due to the difficulties attending their investigation, the very minute size of their parts, and the small number of students who have made a special study of this branch of science. We know, however, amongst other facts, that in all fungi we may recognize two systems, the first, vegetative, which is popularly called the "spawn" (*mycelium*) and which in those kinds parasitic upon crops, rob the plants cultivated of the nourishment necessary for them to produce the most satisfactory results; the second, reproductive, by which the injurious parasite is propagated.

My object in writing these lines is to remind farmers of the serious loss suffered every year from the ravages of one class of these parasitic fungi called "Wheat Smuts," and at the same time to draw their attention to some of the remedies which have been found successful in keeping these parasites within bounds.

It was at one time considered that the difficulties in the way of investigating these parasites were insurmountable, and that it was useless to search for remedies against their attacks. Now, however, sufficient has been discovered to show that there is a wide and fertile field for useful research with great promise of good results. To those who have not time nor opportunities for undertaking these highly interesting but difficult observations, I would earnestly recommend a little book entitled "Diseases of Field and Garden Crops" by Worthington G. Smith, (Macmillan & Co., London, 1884). In this small work of which I have made extensive use in this article, the author has treated of the chief diseases which attack crops, in a plain and simple manner, intelligible to all.

Figs 1 to 3 and 6 to 7 drawn from nature by Mr. Smith are through the courtesy of the publishers taken therefrom. For Figs. 4 and 5, also by the same talented artist, I am indebted to Messrs Edward Webb & Sons, The Queen's Seedmen, Wordsley, Stourbridge, England, who kindly presented me with electrotypes of those excellent figures for this bulletin.

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HARD SMUT, BUNT, STINKING SMUT, SMUT BALLS,

Tilletia caries, (Tul.) AND *T. lævis*, (J. Kuehn).

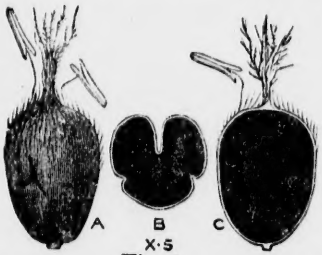

Fig. 1.

A. A "Bunted" grain of wheat.
B. A transverse section of same.
C. A longitudinal section.
(All enlarged 5 diameters)

The diseases of wheat known generally in North America under the name of "Bunt," "Hard Smut," or one of the other designations mentioned above, are due to the ravages of two parasitic fungi belonging to the family *Tilletia*. At Fig. 1, we have a representation of a "Bunted" kernel of wheat in which the whole of the farinaceous contents of the grain have been destroyed by the invading fungus and their place filled by a black powdery dust—the ripe spores of its reproductive system—sometimes called the fruit.

The family to which these parasites belong, was named after a French botanist Matthieu Tillet, who wrote a treatise on the smut diseases of wheat in 1755. *Caries*, the specific name of the commonest kind of Hard Smut in Europe, and which may also cause trouble in Canada, signifies, rotten, and is applied to it on account of the unpleasant odour given out when diseased grains of wheat are crushed. Both of the species mentioned above have at different times received names on account of this ill-odour. *T. caries*, (Tul.) was described by one author as *Uredo fœtida*, and *T. lævis*. (J. Kuehn) once received the very simi' " title of *Ustilago fœtens*, as I

am informed by Prof. W. G. Farlow, of Harvard University, who kindly identified for me specimens of that species received from the North West Territories. The fetid odour is a character which renders these diseases particularly pernicious; for not only does the farmer lose by their ravages a large percentage of the grain produced, but the strong odour of the spores is imparted to the whole crop reaped, and the sound grain is thus reduced in value to the extent, frequently of from 15c. to 20c. per bushel, by having this easily detected "stinking smut" amongst it. Sometimes instances have come under my notice where the whole crop was rendered commercially useless.

Whilst wheat is growing it is very difficult to detect the presence of Bunt; for although the vegetative system of the fungus permeates the whole substance of the wheat-plant attacked, as will be explained further on, it is only in the young kernel of wheat, which is hidden by the chaff, that the characteristic black spores are produced. When wheat-grains have been destroyed by Hard Smut they present an unusual external appearance, which is characteristic of the disease. They are shorter and more swollen (Fig. 1) than in healthy seeds, and from the dark contents showing through the thin skin, are of a dull, greenish-drab colour. They are frequently cracked, as shown at A, when some of the black powdery spores emerge. The figures given herewith show the successive stages in the life-history of *T. caries*, to which it is probable those of *T. lævis*, the commoner North American form, are very similar. If some of these spores be placed under a microscope and highly magnified, to 400 diameters, they will present the appearance shown at Fig. 2.

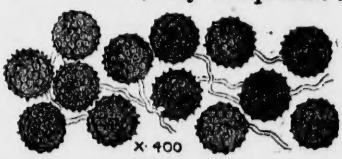

Fig. 2.

These spores, although apparently so large in the illustration, are in reality so exceedingly small that a single kernel of diseased wheat, it is said, will contain four millions of them. The threads shown in the figure amongst these spores are portions of the spawn or vegetative system of the fungus upon which they were produced. The outer coat of the spores presents, as shown in the illustration, a beautiful netted appearance, which, however, is wanting in *T. lævis* where, as the name indicates, the spores are quite smooth.

The germination of the spores and the production of the complete plant therefrom is much more complicated than is the growth of a flowering plant from its seed. It will be found that if one of these spores be examined after it has been kept upon a wet surface for three or four days that it has germinated as shown at Fig. 3 A.

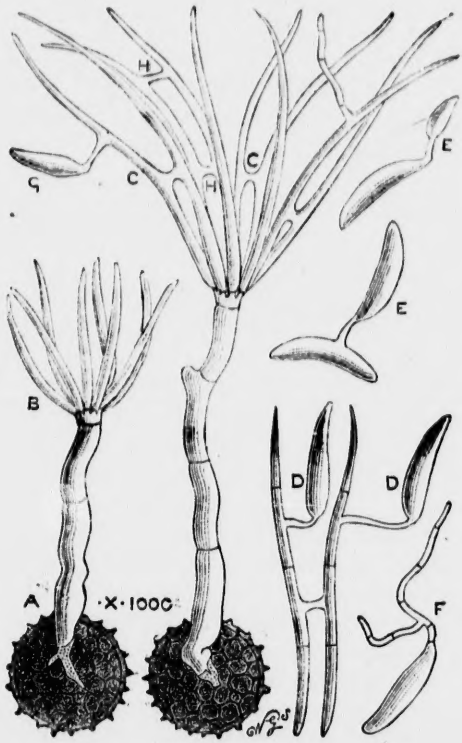

Fig. 3.

This figure is still more highly magnified, being enlarged 1000 diameters. At the point A we see that the outer skin of the spore has burst and a thick jointed tube is protruded. After a time on the end of this tube appear 8 or 10 small protuberances, and upon these again are produced elongated reproductive organs (B). These

bodies although necessary organs of reproduction do not bear the same analogy to the seeds of flowering plants as do the perfect spores (or fruit-spores). They partake more of the character of buds or the small bulblets found upon some plants. They are indeed spores, but are of an inferior class to the perfect spores shown at A, with which we began our examination. By Dr. M. C. Cooke these organs are termed "Sporules of the First Generation," when fully grown they come together and fusion takes place, two or sometimes three becoming united as at C and H by means of short tubes. After this, these conjugated bodies drop from the supporting tube and germinating produce upon short stems other reproductive organs of a different form (D) the "Sporules of the Second Generation." These latter are occasionally produced before the Sporules of the First Generation have dropped from the supporting tube (G), ultimately the Sporules of the Second Generation (D) fall from their attachment and germinating produce similar bodies to themselves, the "Sporules of the Third Generation" (E). When these last named germinate they produce the "Spawn" (*mycelium*) an exceedingly slender jointed thread which ultimately bears the perfect spores. This, however, is not until it has gained admission to its host plant and has forced its way up to the forming seeds.

The ripe spores will not grow as long as they are kept dry, as when stored away with seed-wheat, when however this is sown, they are carried with it into the damp soil, when all the changes illustrated in Fig. 3 take place. It must be remembered, however, that all so far related occurs in and on the soil. After the Sporules of the Third Generation have germinated and the slender thread-like Spawn is produced this grows rapidly and branches in every direction until it comes into contact with a young wheat plant. It now changes its nature and its parasitic life begins. It readily finds its way into the tissues of its host, and running up the stem chiefly through the intercellular spaces, at length reaches the seeds contained in the ear. Fructification now takes place and the spores are produced upon numerous small branches.

These spore-bearing branches are thicker and more gelatinous than those of the ordinary spawn and the spores are formed on little branches which are produced laterally. The spores become free by the drying up of the attaching foot-stalks.

This sketch of the life-history of this parasite from the spore to the perfect state where the spores are again reproduced, is the usual method in which it goes through its different stages. Under certain circumstances, however, which frequently occur, variations may take place at any point in its life-history.

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SMUT, LOOSE SMUT, DUST-BRAND.

(*Ustilago carbo*, TUL.)

Fig. 4.

"Smut," or as it is generally called "Loose Smut," to distinguish it from Bunt or Hard Smut to which it is distantly related, is very injurious to wheat, barley and especially oats, in many parts of Canada. The general appearance as represented at Fig. 4 is too well known. The scientific name *Ustilago* is derived from the Latin word *ustus*, burnt, and the specific name *carbo* means charcoal. Both names refer to the appearance of the spore masses when they are produced in the ear. This disease is not of the same serious nature as Hard Smut, from the fact that the smutted ears are easily observed and can with a little labour be all removed and destroyed before many of the spores are disseminated, and because there being no fetid odour emitted by the spores they do not spoil either the crop of wheat amongst which they grew, or the flour made therefrom.

As with Bunt so with this Loose Smut, it is evident that the disease begins at the bottom and works upwards. Our illustration (Fig. 4) shows us that the lowest spikelets were first attacked, and this is always the case. In all instances when the spores appear in the injured ears the spawn may be detected in every part of the plant from the root through the stem to the inflorescence. In no case, however, can this spawn be found in parts through which it is not necessary for it to pass in order to reach the point where the spores are formed, thus they are not found in the blades of the leaves. This smut is not restricted like Bunt to the seeds alone, but

the whole ear is destroyed. At D (Fig. 5) is shown a spikelet of

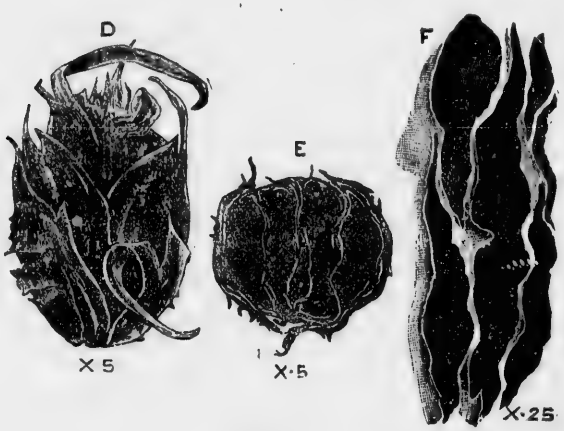

Fig. 5.

wheat including the chaff, which has been destroyed by smut, and at E. we have a transverse section of the same. Here we see that the entire tissues of the spikelet have been destroyed by the infesting fungus. If one of the injured scales of chaff be examined under the microscope it will be found to present the appearance shown at F, where the fungus has burst through the epidermis and brought to light enormous numbers of extremely small spores. These are much smaller than those of Bunt. For comparison they are shown at Fig. 6 magnified to exactly the same extent (400 diameters) as the spores of Bunt shown at Fig. 2.

Fig. 6.

The germination and development of these spores differs somewhat from those of Bunt. At Fig. 7, the different stages of germination are illustrated. These are enlarged to the same degree (1000 diameters) as in the case of Bunt at Fig. 3. When germination takes place a germ tube is produced as at 1. From this are given off as germination advances reproductive organs analogous to buds (2 A.A.), which are the Sporules of the First Generation. These

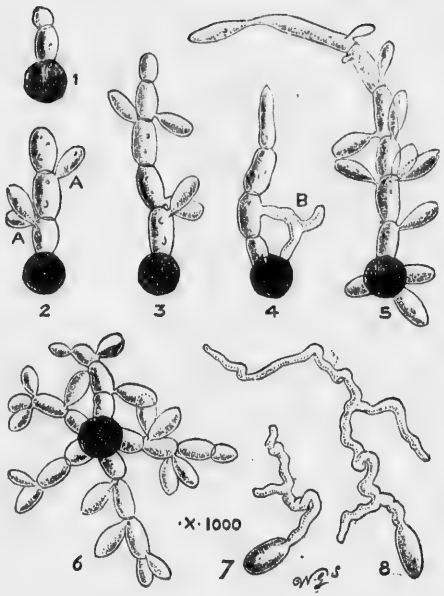

Fig. 7.

come into contact with similar sporules and a conjugation takes place of the same nature as that of the Sporules of the First Generation in Bunt (Fig. 3 C.C.), still further growth is shown at 5 and 6. When long germ-tubes are produced, as at 5, they commonly fuse with other germ-tubes, and then a common sporule-bearing tube is produced bearing the Sporules of the Second Generation. This tube is sometimes extremely long and fine and furnished with numerous joints. The sporules as produced by these germ-tubes are capable of producing others by budding, till at last large colonies are formed separate from the original spore. The last formed sporules, which are very unequal in size, under favourable conditions germinate as at 7 and 8, when the spawn is formed; this now follows the same course as that described under Bunt.

Now all these facts, interesting as they may be, have little practical bearing unless we can draw from them something which may direct

us where to look for a remedy. This, however, they do. Everything seems to point to the infection coming from the ground and travelling upwards. The disease always shows itself on the lowest spikelets of an ear of wheat or panicle of oats. It will always be found, too, that every stem upon an infested plant will show the disease, whilst others in close proximity will show no sign of it.

Mr. Smith in the book before referred to says, at p. 252: "It is easy to prove that Bunt in wheat is propagated by the spores of fungus, for if wheat seeds are dusted with the spores or watered with water containing spores, every wheat plant will come up bunted, whereas neighbouring plants, if not so treated, will come up free from disease."

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REMEDIES.

The nature and life-history of these smut fungi being, as above shown, comparatively well known, some practical remedies have been devised. That some of these remedies have had a decided effect upon the prevalence of the diseases in question is evident. Many instances have been brought under my notice where fields of wheat grown from treated seed have produced crops of perfectly clean grain, whilst close along side of them the crop reaped from seed not so protected was materially reduced by the ravages of these parasites. In Cooke and Berkeley's "Fungi, their Nature, Influence and Uses" p. 225, we find:—"Bunt is another pest which occupies "the whole farinaceous portion of the grains of wheat. Since dress-"ing the seed-wheat has been so widely adopted in this country *, "this pest has been of comparatively little trouble."

In the Report of the Botanist to the New York Agricultural Experiment Station for 1886 (p. 129), in an account of experiments made by Mr. C. S. Plumb, with different remedies for smut in oats, we find as follows:—"In every one of the ten experiments the testimony is "positive in demonstrating that good has resulted from the treatment "of the seed."

* England.

All grain for seed should, of course, be procured as free as possible from smut; but when there is the slightest doubt about its presence, the trouble and expense of treating the seed are so small that there is no excuse for not doing so.

The condition in which the smuts pass the winter, is in the shape of the minute black spores produced in the ears of wheat. These spores either adhere to the ripe grain of adjacent wheat plants, or falling to the ground remain there, in an undeveloped condition, until the young wheat plant has attained the proper growth for them to begin their attack. By a proper system of rotation of crops, wheat would not be grown again on the same land for about 4 or 5 years, or more, and by this time it is probable that most of the spores from smut upon the previous wheat crop would have perished.

The remedies which have been most successful are those in which methods have been adopted, to destroy the spores adhering to the seed-wheat previous to sowing. To accomplish this it is necessary to wash the grain thoroughly or to steep it in some weak poisonous solution, so as either to remove or to destroy the fungous germs without injuring the germinating qualities of the seed, and, moreover, it seems highly probable that a sufficiency of the material used for this purpose will adhere to the seed and protect it against the attack of any spores which may be present in the soil at the time the wheat is sown.

Of a great many remedies which have been tried with more or less success, I select the three following as being in my opinion, the best both for efficiency and convenience. The first and second I have myself frequently tried with manifest success. The third is given on the authority of Mr. Worthington G. Smith.

1. Sulphate of Copper, also called "Bluestone" or "Blue Vitriol."

This substance can usually be procured in any part of Canada from Druggists or General-store Keepers, at about 10 cents per lb. so that the cost of treating seed with the strongest solution recommended below, would not exceed 2½ cents per bushel. The different methods of applying this substance to the grain vary slightly; but the differences are merely with regard to the extent

to which it is deemed advisable to wet the seed. Some advise soaking the grain; but it would appear from the results of many experiments that this is not necessary. Mr. Worthington G. Smith advises the following: "1 lb. of bluestone dissolved in 5 "quarts of boiling water is sufficient for a sack of four imperial "bushels. The wheat is soaked for 10 minutes, or the 10 pints of "solution may be poured over till all is absorbed."

Mr. S. A. Bedford of Moosomin, N.W.T., who has had considerable experience as a farmer in Manitoba and the North-West Territories, tells me that the following method has proved successful in his district.

"One pound of Sulphate of Copper is dissolved in a pailful of hot "water, which is then sprinkled by one person over 10 bushels of "wheat placed in a waggon box, whilst some one else keeps the grain "well stirred. Should a large amount of smut be detected in grain "required for seed, the solution is made stronger, double the "quantity of bluestone being used."

The chief advantage claimed for this method is that in a few hours the grain is sufficiently dry to sow with the drill.

Mr. C. S. Plumb, of the New York Experimental Station, used 4 oz. of Sulphate of Copper in one gallon of water, and reports that "seeds soaked seventeen and a-half hours in this solution were found "to produce a slight amount of smut. Soaked forty hours all "germs of the fungus were killed."

It is to be noted that Mr. Plumb's experiments were with oats, in which, from the fact that the seed is contained inside a comparatively loose husk, there is much more difficulty in removing or destroying all the smut-spores than is the case with the smooth and naked grains of wheat.

2. Brine and Lime.

A remedy generally available at country farm houses and from which good results have been secured, is to soak the grain for 10 or 15 minutes in brine of the ordinary strength used for pickling pork (*i.e.* in which a fresh egg will float). If well stirred many of the smut spores, smutty and imperfect grains, &c., will rise to the surface, and can be skimmed off and destroyed. After the brine is

poured off, the wheat must be dried by dusting lime over it until all the grains are white.

It is claimed that sprinkling the brine on the grain instead of soaking it as above, before dusting it with lime has been found successful; but I have never tried this method.

3. Alkaline Water.

It might happen that none of the above-mentioned materials were obtainable and in such case the mere washing of the seed would be beneficial. Mr. Smith says "as the spores are lighter than water "steeping in brine or even pure water is often effectual, as the spores "float, and are easily washed away. Some alkaline ley should be "added if water is used, as the oil on the surface of the spores com- "bines with the alkali and forms a soapy substance which is fatal to "effectual spore germination."

An alkaline ley suitable for the above purpose may be made by adding to three or four gallons of boiling water, in any suitable vessel, one gallon of hard-wood ashes and stirring frequently until the alkaline properties of the ashes are extracted; or an alkaline solution of sufficient strength may be made by dissolving about 2 lbs. of ordinary washing soda in a pailful of water.